# C & EE 141

## Composite Beam Design
## Part 2

# Effective Moment of Inertia of Composite Section

- Moment of Inertia of a composite section changes with the magnitude of the applied moment
- Need to calculate the transformed section properties of the composite section ($I_{equiv}$)
- Need to use service loads to get an accurate value

# Effective Moment of Inertia of Composite Section

- Calculation of $I_{equiv}$ is cumbersome
- Acceptable to use lower bound $I$ instead ($I_{LB}$)
- $I_{LB}$ is for section participating at required strength rather than at service level loads

# Lower Bound Moment of Inertia

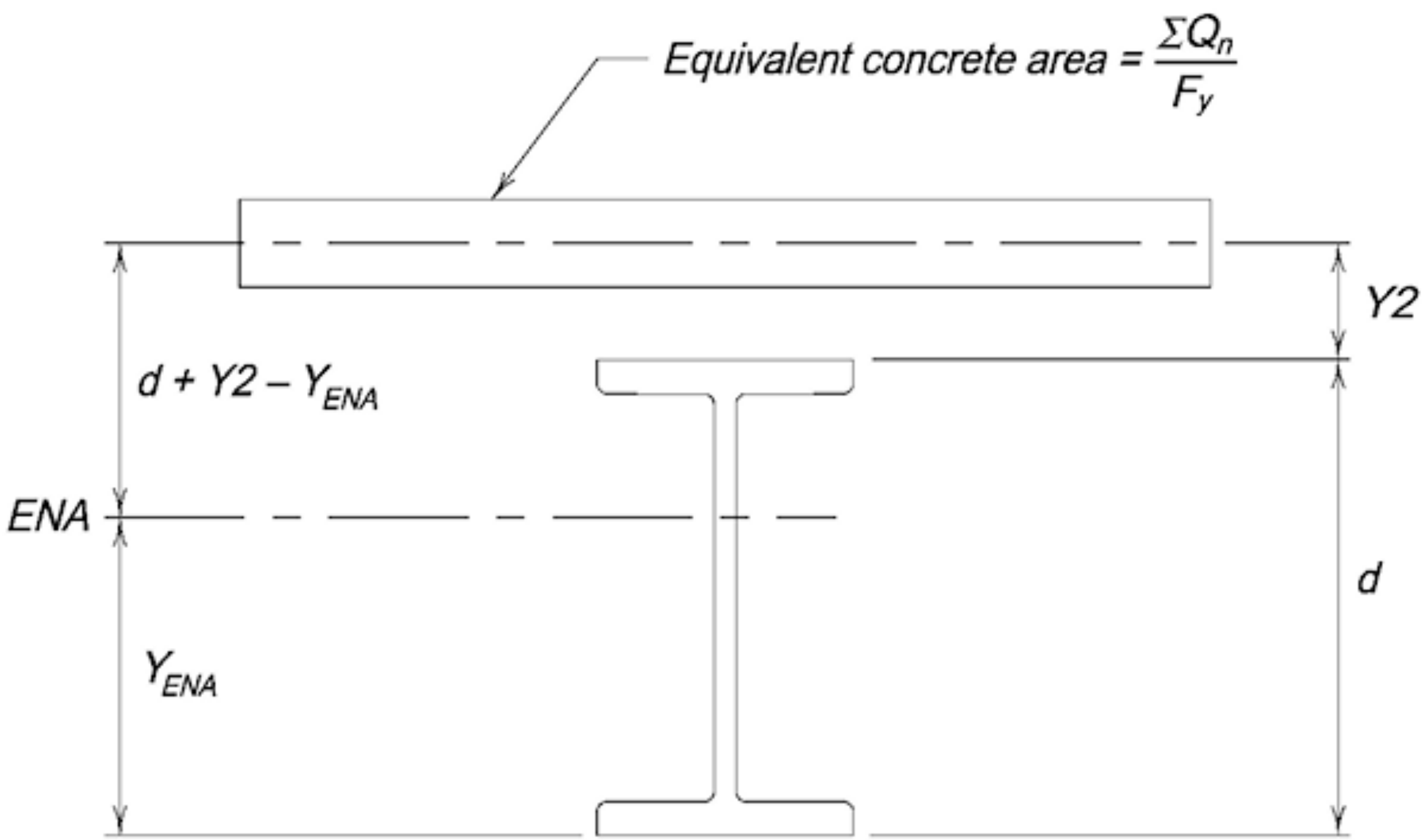



*Fig. 3-4. Deflection design model for composite beams.*

# I Lower Bound

$$I_{LB} = I_s + A_s(Y_{ENA} - d_3)^2 + (\Sigma Q_n / F_y)(2d_3 + d_1 - Y_{ENA})^2 \qquad \text{(C-I3-1)}$$

where

$A_s$ = area of steel cross section, in.$^2$ (mm$^2$)

$d_1$ = distance from the compression force in the concrete to the top of the steel section, in. (mm)

$d_3$ = distance from the resultant steel tension force for full section tension yield to the top of the steel, in. (mm)

$I_{LB}$ = lower bound moment of inertia, in.$^4$ (mm$^4$)

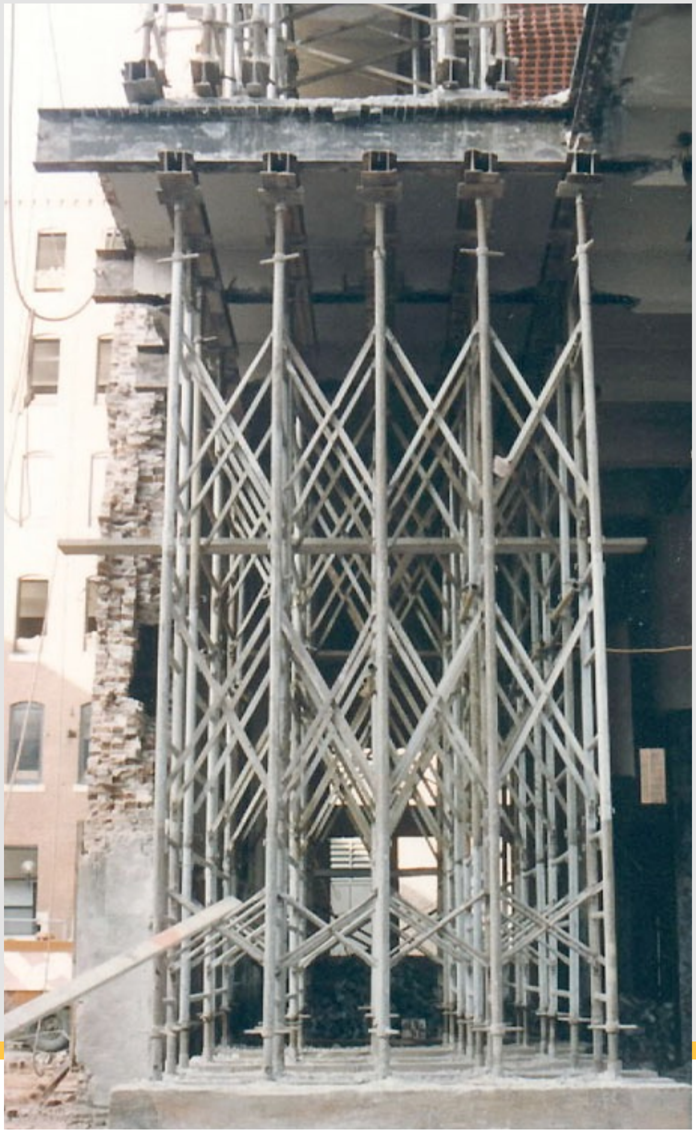
$I_s$ = moment of inertia for the structural steel section, in.$^4$ (mm$^4$)

$\Sigma Q_n$ = sum of the nominal strengths of steel anchors between the point of maximum positive moment and the point of zero moment to either side, kips (kN)

$$Y_{ENA} = [A_s d_3 + (\Sigma Q_n/F_y)\,(2d_3 + d_1)]/[A_s + (\Sigma Q_n/F_y)], \text{ in. (mm)} \qquad \text{(C-I3-2)}$$

# Shoring: When and Why?

- Steel framing must satisfy two loading & resistance conditions
  - Steel beam alone supporting wet concrete & construction live load (temporary)
  - Composite beam supporting final dead and live loads (permanent)
- The temporary condition can be eliminated if shoring is provided to support the beam until the concrete hardens



# Shored vs Unshored

- Unshored
  - Weight of wet concrete supported by beam prior to composite action
  - Heavier beams
  - No additional construction time or money for shoring
- Shored
  - Weight of wet concrete supported by shoring until concrete cures
  - Lighter beams
  - Additional construction time and money for shoring

**More Material & Less Labor**

**Less Material & More Labor**

**Unshored is typical for USA**

# Unshored Construction Considerations

- Beam must satisfy strength and deflection for both *pre-composite* and *post-composite* conditions
- *Post-composite* loads are dead and live loads as discussed previously
  - Live loads per code
  - Dead loads for finished building

# Unshored Construction Considerations

- *Pre-composite* loads are dead and live loads that occur prior to the hardening of the concrete deck.
  - Loads must be supported by beam alone without contribution of slab.
    - Consider braced/unbraced condition as appropriate.
  - Dead loads
    - Self weight of framing
    - Wet weight of concrete slab
  - Live loads
    - Construction personnel and materials on deck
    - 20 psf typical value (similar to roof live load)

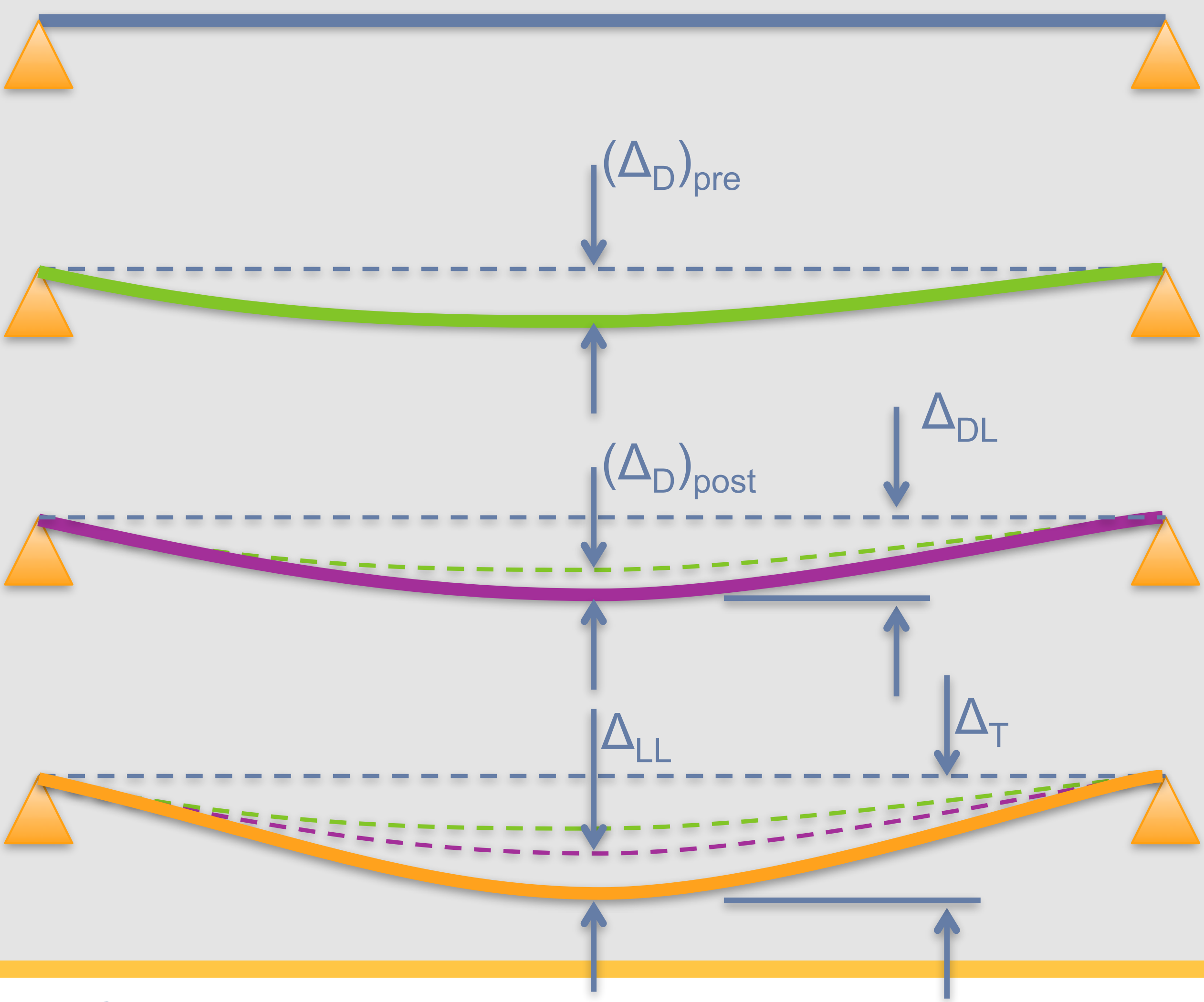
# Deflection for Unshored Construction

- *Pre-composite* deflections resulting from wet weight of concrete are "locked in" when concrete sets and hardens
  - *Pre-composite* deflections depend on stiffness of the beam alone
  - Contribute to total deflection of member that is compared to L/240 criteria
  - *Pre-composite* live load deflections are not permanent and not typically considered a serviceability limit state

# Deflection for Unshored Construction

- *Post-composite* deflections include all dead loads and live loads occurring after hardening of concrete deck
  - *Post-composite* deflections depend on stiffness of the composite section
  - Compare to total load deflection limit and live load deflection limit

# Deflection for Unshored Construction




Unloaded beam

Pre-composite dead load applied, concrete in plastic state ($I_{beam}$)

Post-composite dead load applied, concrete in hardened state ($I_{equiv}$)

Occupancy live load applied, concrete in hardened state ($I_{equiv}$)

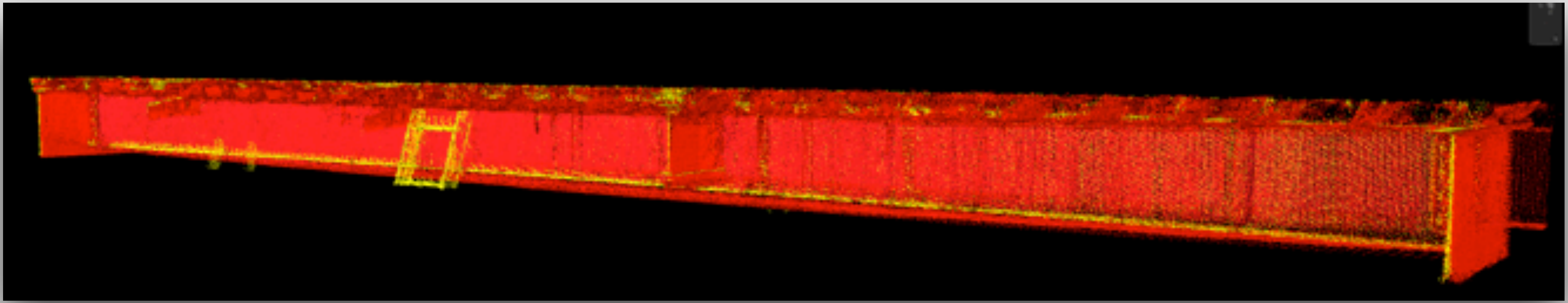
# Camber

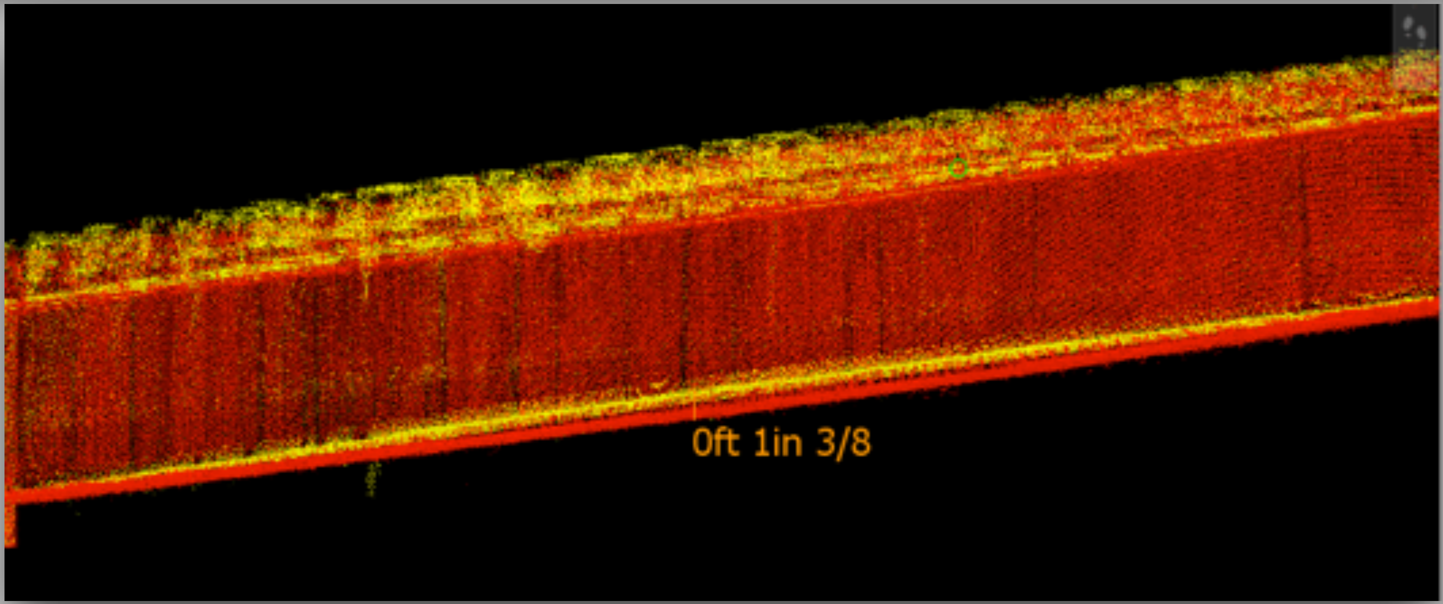
- Beam can be given slight upward bend in the fabrication shop to offset the pre-composite deflection
- Typically camber if pre-composite deflection exceeds ¾”
- Camber ¾” minimum and increased in ¼” increments

# Camber

- Deflections are difficult to predict and too much camber can result in high points in floor.
- Therefore, typical practice is to calculate camber based on 80% of pre-composite dead loads.
- Round down to next smaller ¼” increment to specify camber.

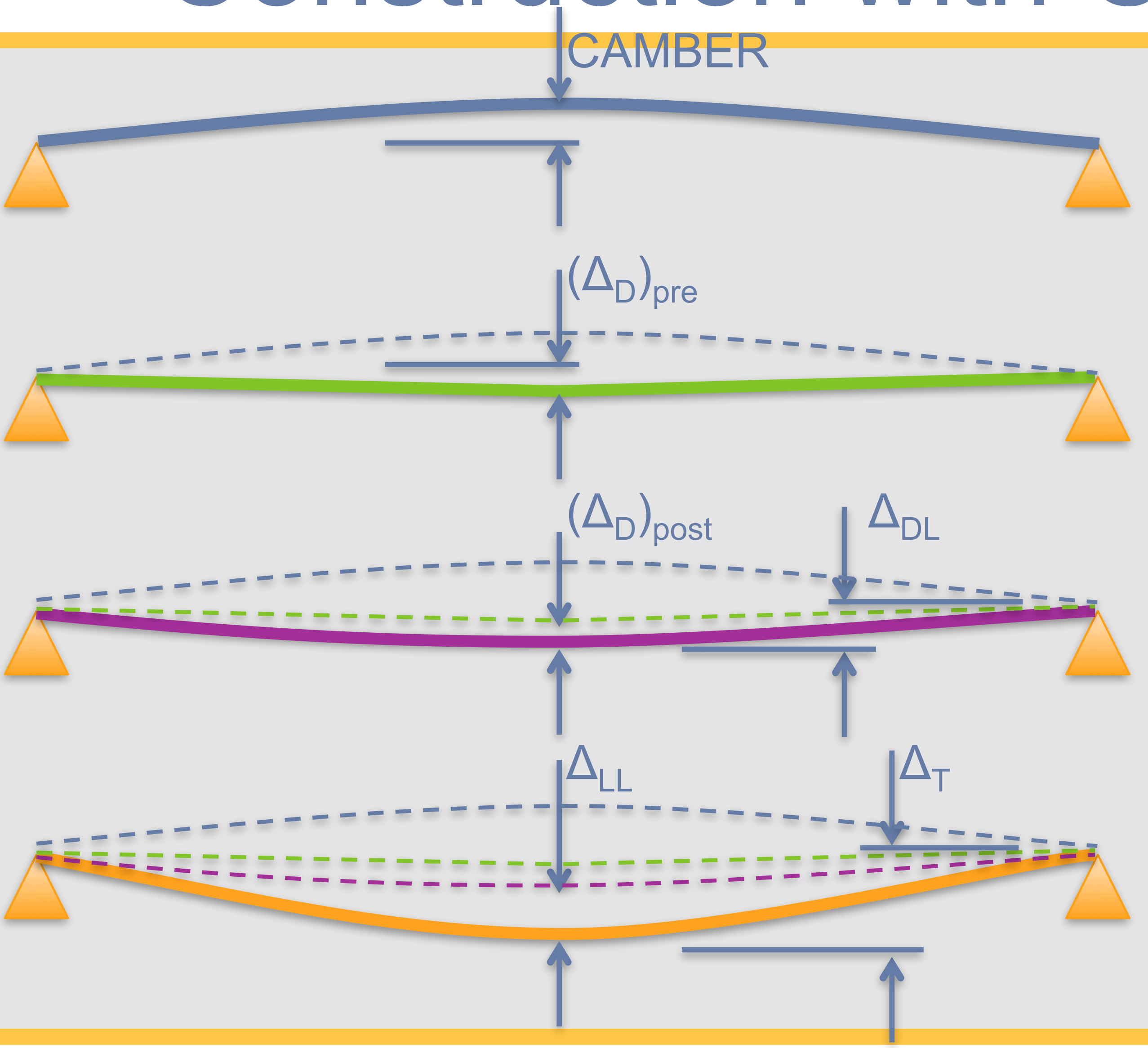
# Deflection for Unshored Construction






Yellow: cambered beam before slab poured
Red: deflected beam after slab poured

# Deflection for Unshored Construction with Camber




Unloaded, cambered beam

Pre-composite dead load applied, concrete in plastic state ($I_{beam}$)

Post-composite dead load applied, concrete in hardened state ($I_{equiv}$)

Occupancy live load applied, concrete in hardened state ($I_{equiv}$)

# Questions

# EXAMPLE PROBLEMS